De Broglie waves, periodic process and the theory of relativity.

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To begin with, let us recall how the wave nature of particles was discovered.

In order to harmonize the theory of relativity with a quantum phenomenon (a periodic process in elementary particles), Louis de Broglie was forced to introduce the concept of “matter wave” in relation to a moving particle (for example, an electron). De Broglie's reasoning was as follows.

Light, that is, electromagnetic radiation, can exhibit the properties of both particles (photons) and waves (electromagnetic wave). The energy of a quantum of electromagnetic radiation is equal to:

$$E = h * \gamma$$

Therefore, there must be a periodic process associated with a radiation quantum (photon), since the formula contains a frequency (γ), which, by definition, is a characteristic of a periodic process.

$$E = h * \gamma = m * c^2$$

$$\gamma = (m * c^2) / h$$

Further, de Broglie suggested that a similar periodic process exists in all elementary particles, including those with a rest mass. Agree that his logic is impeccable and understandable. Here is the quote [1, 2]:

“In quantum theory, I assumed that there is a periodic process associated with the electron as a whole (the material point). This process for an observer stationary relative to an electron would occur over the whole space with the same phase and would have a frequency $\gamma = (m * c^2) / h$.”

De Broglie tried to answer the question: what would an external observer see in this case?

After reflection, de Broglie came to the conclusion that an external observer, relative to which a particle (of mass m) is moving at a speed v, will see a “matter wave” of length λ:

$$\lambda = h / (m * v)$$

That is, an external observer will see the de Broglie wave.

Usually, the de Broglie formula is extended to all objects and particles that have mass, including macro objects. But, de Broglie waves are a consequence of a periodic process that occurs in elementary particles.

Moreover, the energy of this process is directly related to the momentum of the particle, as a result, we get the dependence of the wavelength on the momentum of the particle - the de Broglie formula.

Therefore, strictly de Broglie's formula can be applied only to elementary particles, since not every particle with momentum is also characterized by a certain “internal” periodic process. Although, some compound particles, for example, a proton, a neutron, etc., may well have an impulse and a certain “internal” periodic process.

And one more important conclusion.

The speed of the particle and the speed of the de Broglie wave are related by the following relation:

$$v * vf = c^2$$

where v is the speed of the particle,

vf - de Broglie wave speed.

That is, based on the relation, the speed of an elementary particle (for example, an electron) will always be less than the speed of light, since the speed of de Broglie waves is always greater than the speed of light. And only in the case of electromagnetic radiation, their velocities are equal: the speed of a particle and the speed of a wave are equal to the speed of light.

Consequently, from de Broglie's wave description it strictly follows that particles with rest mass will always move at speeds less than the speed of light.

That is, any macro-objects that consist of elementary particles (and these are all macro-objects!), will never be able to overcome the speed of light.

1. Louis de Broglie. Selected Works. Volume 1. The formation of quantum physics: the work of 1921-1934. Moscow, Logos, 2010, page 203 (About frequency of the electron).

2. Louis de Broglie. Sur la frequence propre de Pelectron. Compt. Rend. 1925. 180. P. 498.